

TEST OF AN ARRAY OF END-FED UNELEVATED 1200-FOOT (365.8-METER) WIRE ANTENNAS

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Change History

Date	Description
2025 July	No changes; initial version
2025 August	<ul style="list-style-type: none">• Revised Introduction to better describe the history of the author's experiments with end-fed, unelevated wire antennas• Revised Introduction to better describe the antennas and clarify they were not of the Beverage or Beverage-on-ground design• Revised Test Site to state the test site was near Del Sur, California• Revised Antenna Array to clarify the antenna wire was not chosen for any specific technical reason• Added the number of stations logged to Results• Renamed the "Gain" section to Signal Strength• Changed instances of "gain" to "signal strength" or "signal strengths"• Added a comment to Conclusions about the utility of these antennas in the 160 and 80-meter amateur radio bands.

Introduction

In the mid-1980s the author discovered that lowering an end-fed random insulated wire antenna to the ground did not affect mediumwave reception. This spurred him to experiment with other unelevated insulated wire antennas of various lengths up to 5000 feet (1524.0 meters).

These experiments culminated with the deployment and testing an array of unelevated 1200-foot (365.8-meter) long wire antennas on 1988 January 30-31. The notes from this test were found in 2020 and later converted to digital form, refined, and prepared for publication.

The antennas used in the above experiments were simply end-fed random wires laid on the ground. They did not use a terminating resistor or ground connection at the far end or any impedance matching between the antenna and receiver. The author was not trying to use them as Beverage or Beverage-on-ground antennas.

Objective

The primary objective of the test was to characterize the directivity of unelevated wire antennas 1200 feet (365.8 meters) in length. The author also hoped to use the antenna array to receive longwave and mediumwave stations he had not previously logged.

Test Site

The antenna test site was located near Del Sur, California at $34^{\circ} 41' 22''$ (34.6895°) N and $118^{\circ} 19' 49''$ (118.3304°) W or 10.6 statute miles (17.0 kilometers) west of Lancaster-city hall and 44.1 statute miles (71.0 kilometers) north of Los Angeles city hall (Figure 1). The site elevation was 2559 feet (780 meters) above sea level.

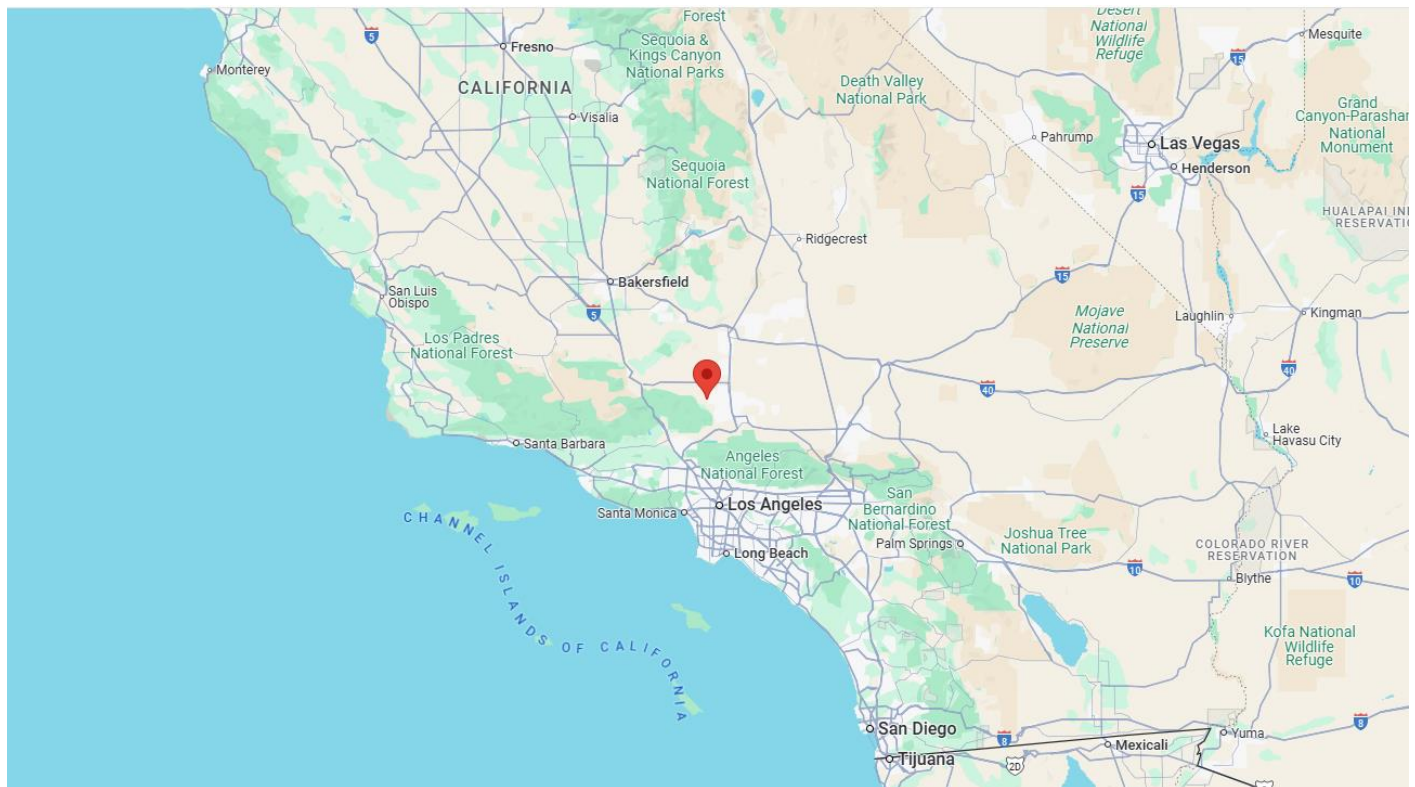


Figure 1. Test site location. Image courtesy of Google Maps.

The site was flat with dry, hard ground and sparse vegetation (Figure 2). It was used because its lack of interference from Los Angeles area mediumwave broadcast stations, large expanse of barren land, flat terrain, and convenient location.



Figure 2. The terrain and vegetation in the antenna test area photographed in 2023 December.

Radio Propagation

The test was conducted during northern hemisphere winter between approximately 15:30 - 21:30 PST on January 30 and 08:15 - 17:00 PST on January 31. During the test, propagation was primarily influenced by the time of day. Figure 3 summarizes the testing activities versus the time of day.

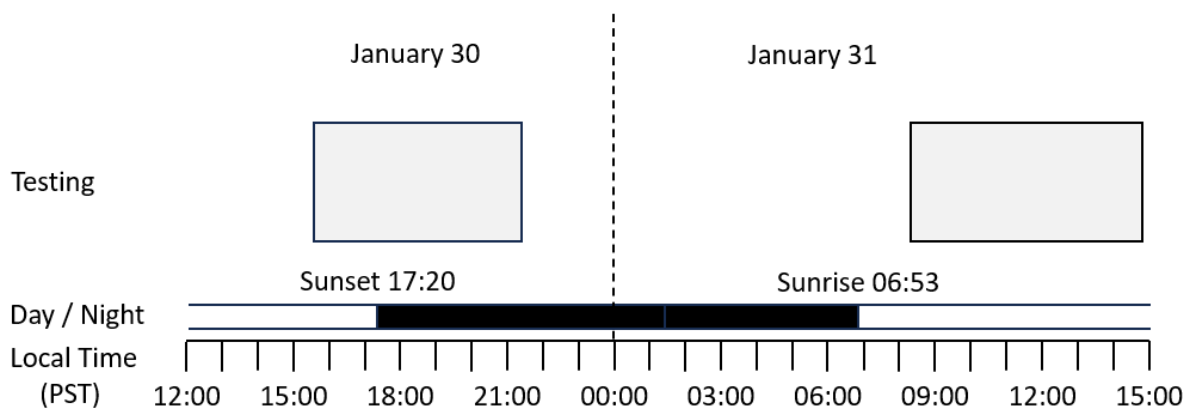


Figure 3. Testing timeline.

Receiving System

The receiving system used for the test consisted of the antenna array and an antenna switch box, communications receiver, and digital demodulator (Figure 4).

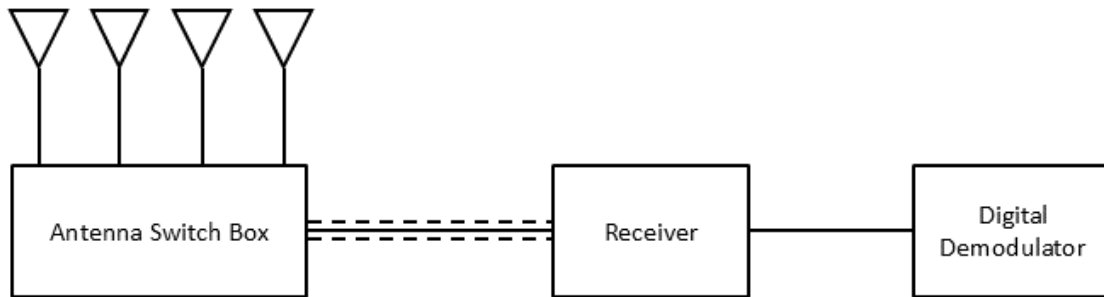


Figure 4. Receiving system.

Antenna Array

The antenna array consisted of four antennas, each of which was a 1200-foot (365.8-meter) length of 24-AWG (0.511-millimeter) diameter stranded and solid conductor wire with thick plastic insulation. The wire gauge was not specifically chosen for this test. It was the gauge of the available wire. The wire length was selected because it was believed to be long enough to exhibit directivity and good signal strengths, but short enough for easy handling.

The wires were laid on the ground in straight lines that radiated away from the author's vehicle at headings of 315°, 000°, 045°, and 088° from true north (Figure 5). Rather than running east-west parallel to Avenue J, the 088° / 268° wire was deployed away from the road at an angle to reduce reception of motor vehicle ignition noise.

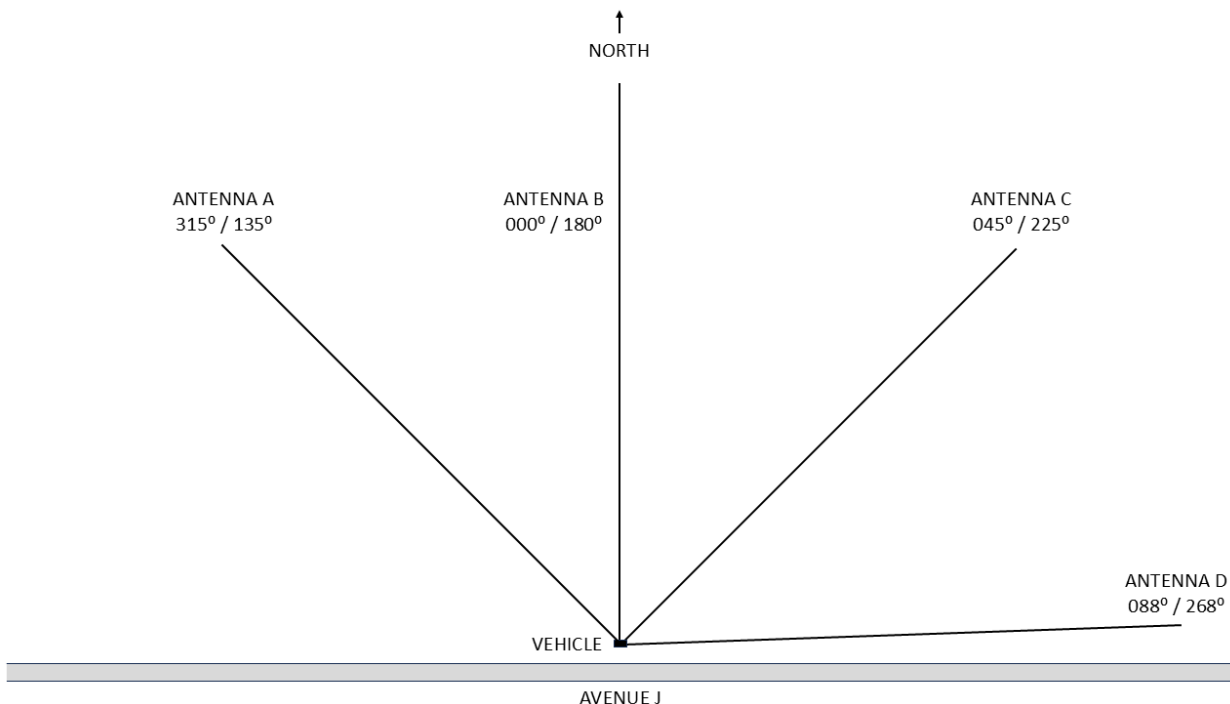


Figure 5. Antenna array plan view (approximately to scale).

The end of each antenna farthest from the receiver was not grounded and the antennas were fed to the receiver without any impedance matching.

Antenna Switch Box

The antennas were connected to a switch box which in turn was connected to the receiver by a coax jumper cable. Each antenna was connected to a three-position switch that allowed the antenna to be disconnected or connected to the receiver via the coax center conductor or outer ground braid. For these tests, the antennas were connected one at a time to the coax center conductor and fed into the receiver's antenna input.

Communications Receiver

Antenna performance was evaluated using a Realistic DX-302 communications receiver. It featured a triple conversion, synthesized design, and received from 5 to 30000 kHz.

Digital Demodulator

An Advanced Electronic Applications MBA-RO digital demodulator was brought to the site to convert received Morse Code and teletype audio to text.

Ground

The communications receiver was not grounded because the hardness of the ground would make driving a ground rod into the earth difficult. It was also doubtful that the site's assumed low soil conductivity would provide a sufficient ground to improve reception. The only ground connection used was to the automobile body via the -12V power lead.

Results

Twenty-two previously unlogged stations were received during this test (Table 1) and used to characterize the directivity and received signal strengths provided by the antennas.

Directivity

Table 1 lists the number of antennas that received each logged station with a signal strength of weak or greater.

Table 1. Number of antennas receiving each station.

Freq. (kHz)	Callsign	Location	Number of Antennas Receiving Station (Directivity →)			
			4	3	2	1
309	XFL	Mazatlán, Sinaloa, Mexico				X
314	F	Farallon Island LS, California				X
317	CVP	Helena, Montana			X	
320	HTN	Miles City, Montana			X	
326	DC	Princeton, British Columbia		X		
334	STI	Mountain Home, Idaho		X		
351	NO	Reno, Nevada			X	
354	ZES	Cape Scott, British Columbia				X
356	SA	Sacramento, California				X
367	MO	Modesto, California			X	
400	HU	Sacramento, California				X
850	KMDY	Thousand Oaks, California		X		
990	KKIS	Pittsburg, California			X	
1130	CKWX	Vancouver, British Columbia		X		
1230	KSZL	Barstow, California			X	
1270	KFIY	Tulare, California		X		

Freq. (kHz)	Callsign	Location	Number of Antennas Receiving Station (Directivity →)			
			4	3	2	1
1270	KPLY	Sparks-Reno, Nevada			X	
1440	KUHL	Santa Maria, California				X
1510	KGA	Spokane, Washington	X			
1590	KCIN	Victorville, California			X	
8566	ZSJ4	Silvermine, South Africa	X			
10004	RID	Irkutsk, USSR			X	

Figure 6 shows how many stations were received on how many antennas. The fewer the number of antennas that received a station, the greater the directivity. For the purposes of this paper, directivity was exhibited if a station was received on two or one antennas.

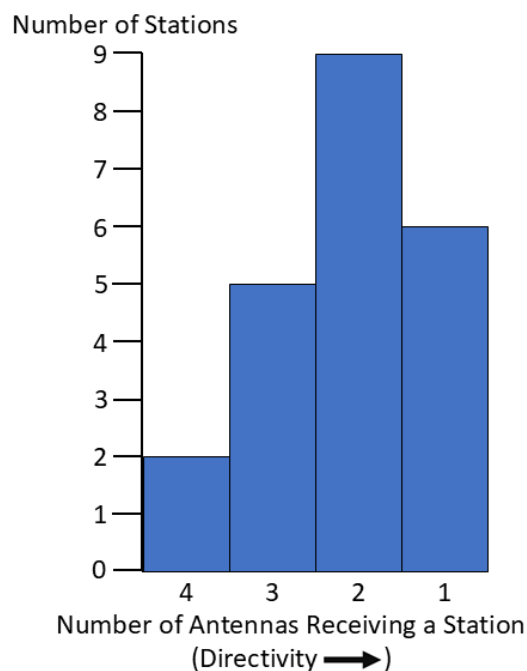


Figure 6. Number of stations heard versus the number of antennas.

According to the graph, two stations were heard on all four antennas, indicating low directivity. Conversely, six stations were heard on one antenna, indicating high directivity. The metric for the number of stations received on only one antenna may be misleading because these stations were weak. Had they been stronger, they may have been heard on more than one antenna. The graph shows the antenna array exhibited directivity for 65% of the stations received.

For stations whose bearings from the test site were known, the angle of each station off the axis of the antenna providing the strongest signal was plotted versus the station frequency (Figure 7). The intent was to determine if the directivity varied with frequency and to define the angles off the antennas providing the strongest signals.

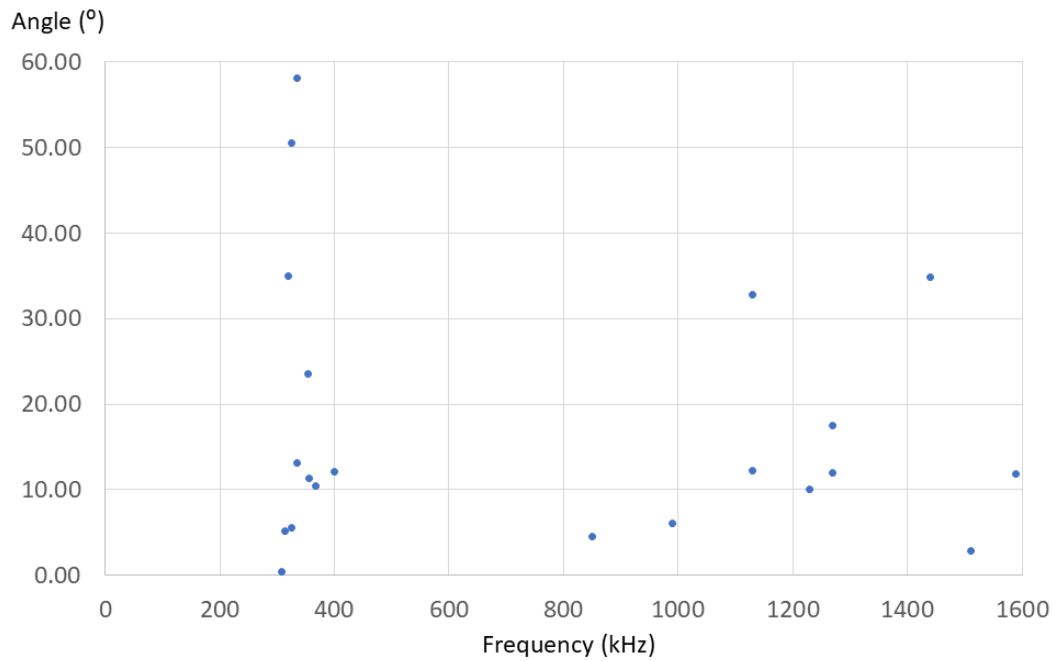


Figure 7. Station angle off the antenna providing the strongest signal versus frequency.

As shown in the graph, the station angle off the best antenna varied from 0.4 to 58.1° on longwave and 2.9 to 34.8° on mediumwave. The average of these angles was 20.5° on longwave and 14.5° on mediumwave.

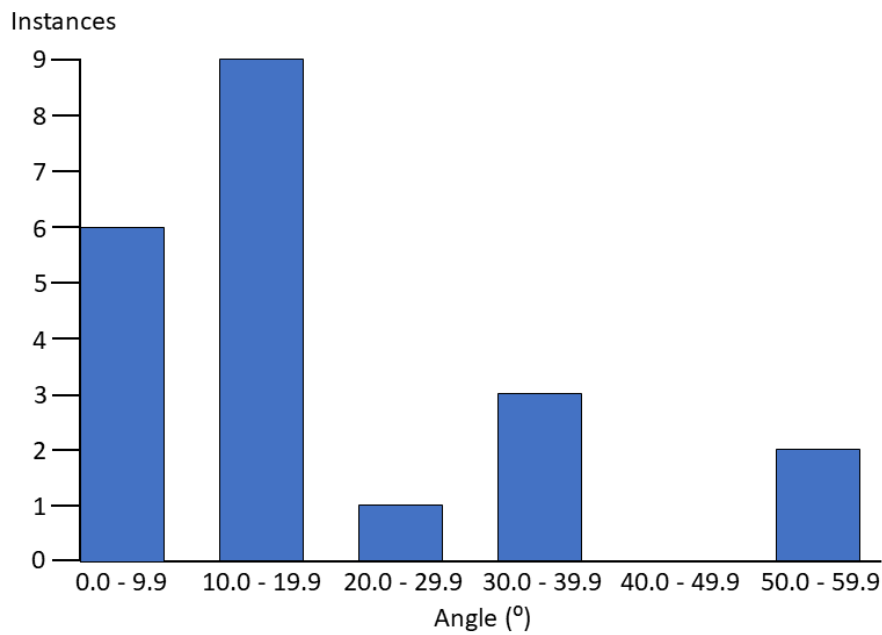


Figure 8. Station angle off the axis of the antenna providing the strongest signal.

Signal Strength

The limited amount of testing makes it difficult to characterize the signal strengths provided by the type of antennas used in the array. In many cases, they exhibited good received signal strengths on longwave. On mediumwave the signal strengths were greater and significant in a few instances.

Table 1. Summary of station signal strengths.

Freq. (kHz)	Callsign	Location	Power (W)	Distance		Local Time (PST)	Signal Strength
				Statute Miles	km		
309	XFL	Mazatlán, Sinaloa, Mexico	100	1066.1	1715.7	20:50-20:59	Weak
314	F	Farallon Island LS, California	150	333.3	536.4	17:58-18:03	Weak
317	CVP	Helena, Montana	100	Unknown	Unknown	18:12-18:18	Good
320	HTN	Miles City, Montana	200	1036.4	1668.0	18:24-18:29	Good
326	DC	Princeton, British Columbia	1000	1026.2	1651.4	18:37-18:48	Good
334	STI	Mountain Home, Idaho	50	598.6	963.3	21:05-21:12	Good
351	NO	Reno, Nevada	25	Unknown	Unknown	21:15-21:23	Good
354	ZES	Cape Scott, British Columbia	1000	1221.2	1965.3	18:58-19:04	Fair
356	SA	Sacramento, California	25	314.9	506.8	08:18-08:26	Weak
367	MO	Modesto, California	25	243.8	392.4	13:44-13:51	Good
400	HU	Sacramento, California	25	326.1	524.9	08:42-08:51	Fair
850	KMDY	Thousand Oaks, California	Unknown	44.1	70.9	09:17-09:29	7.0 S-units
990	KKIS	Pittsburg, California	5000	304.9	490.7	09:39-09:56	5.5
1130	CKWX	Vancouver, British Columbia	50000	1027.3	1653.3	16:53-17:07	S-20
1230	KSZL	Barstow, California	1000	75.7	121.7	12:04-12:19	S-10.5
1270	KFIY	Tulare, California	5000	119.2	191.8	15:33-15:49	S-10
1270	KPLY	Sparks-Reno, Nevada	5000	342.1	550.5	15:57-16:09	S-20
1440	KUHL	Santa Maria, California	5000	122.3	196.9	12:40-12:51	Weak
1510	KGA	Spokane, Washington	50000	892.0	1435.5	17:16-17:25	S-20
1590	KCIN	Victorville, California	500	59.0	94.9	12:58-13:11	S-7.5
8566	ZSJ4	Silvermine, South Africa	5000	Unknown	Unknown	19:40-19:55	Good S-6
10004	RID	Irkutsk, USSR	Unknown	Unknown	Unknown	16:31-16:39	S-3

For example, KPLY, a 5000 W station on 1270 kHz in Reno-Sparks, Nevada had a signal strength of S-20 over a range of 342.1 statute miles (550.5 km) more than an hour before sunset. In addition, KKIS, a 5000 W station in Pittsburg, California on 990 kHz was received with a strength of S-5.5 from 304.9 statute miles (490.7 km) during midmorning. Finally, KCIN, a 500 W station on 1590 kHz in Victorville, California had a signal strength of S-7.5 from a range of 59.0 statute miles (94.9 km) during midday.

The author's testing concentrated on the longwave and mediumwave regions. A cursory check of antenna performance on shortwave showed they provided satisfactory signal for the two stations logged.

Conclusions

The antennas were tested from 309 to 10005 kHz and exhibited directivity and good received signal strength in many cases. Overall, they appeared to offer the best performance on mediumwave. Unelevated, end-fed wire antennas of this type may provide a simple means of obtaining good reception on longwave through shortwave (including the 160 and 80m amateur radio bands) provided a large enough area is available for their deployment.

Appendix

This appendix contains data sheets for the stations logged during the test. The information was transcribed from the original handwritten logging sheets. Each data sheet contains entries for the following information:

Frequency (kHz)	The station frequency in kilohertz.
Local Date / Time (PST)	The local date and time, in Pacific Standard Time, at the antenna test site when the station was heard.
UTC Date / Time	The date and time, in Coordinated Universal Time, at the antenna test site when the station was heard.
Receiver Selectivity	The receiver IF bandwidth used.
Receiver Mode	The mode used to receive the station.
Digital Demodulator	Indicates if the MBA-RO was used to demodulate a non-voice signal
Type of Signal Heard	The type of signal received.
Station Callsign	The station's callsign
Station Location	The general location of the station.
Station Coordinates	The latitude and longitude of the station's antenna in degrees, minutes, and seconds and decimal degrees. This information was obtained from various sources.
Station Power	The station's transmit power in Watts.
Station Bearing	The station's direction with respect to the test site measured in degrees clockwise from true north. It was obtained using a great circle calculator and a WGS84/NAD83/GRS80 Earth model.
Station Distance	The station's distance from the test site in statute miles and kilometers. These values were computed separately using a great circle calculator, WGS84/NAD83/GRS80 Earth model, and an output of statute miles or kilometers.
Station Angle Off Best Antenna	The angle of the station off the axis of the antenna that provided the strongest signal.
Comments	This information contains selected comments transferred from the original logging sheet and comments added during preparation of this report.
Signal Strength	<p>The strength of received signals was assessed using subjective terms (for example, "Fair"), S-unit measurements using the receiver's signal strength meter (for example, "5.5," "3.0 S-units," "S-20"), or both.</p> <p>The meter had markings for 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, S-9 +10, and S-9 +30 S-units. A reading of S-0 represented no measurable signal strength while S-9 +30 corresponded to the maximum measurable signal strength. For simplicity, signal strengths above S-9 were noted using a shorter format such as 10, 15, 20, S-20, and so on.</p>
Manmade Interference	Described as "nil," "slight," "moderate," "severe," "extreme," or "--" (not applicable).

Fading Depth (S-units)	The depth of fading of the received signal described as “none,” “nil,” or “could not measure;” S-unit measurements using the receiver's signal strength meter (for example, “2.5” or “5 S-units”); or the “–” (not applicable) symbol.
Fade Duration (sec.)	The duration of signal strength fades, in seconds. This entry can also contain comments regarding the fade duration (for example, “could not measure”) or the “–” (“not applicable”) symbol.
Noise	Assessed using a scale of nil, slight, moderate, severe, or extreme. Also described as “could not measure” and – (“not applicable”).

XFL

Frequency (kHz): 309
Local Date / Time (PST): 1988 January 30 20:50-20:59
UTC Date / Time: 1988 January 31 04:50-04:59
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: XFL
Station Location: Mazatlán, Sinaloa, Mexico
Station Coordinates: 23° 14' (23.233333°) N
 106° 27' (106.45°) W
 Source: *A Guide to the Baja California Field Studies Program*
Station Power (W): 100
Station Bearing: 134.6°
Station Distance: 1066.1 statute miles (1715.7 km)
Station Angle Off Best Antenna: 0.4°

Comments: Continuously sent "XFL" in CW then a tone

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Weak	Inaudible	Inaudible	Very weak
Manmade Interference	Moderate	–	–	Severe
Fading Depth (S-units)	Could not measure	–	–	Could not measure
Fade Duration (sec.)	Could not measure	–	–	Could not measure
Noise	Slight	–	–	Slight

F

Frequency (kHz): 314
Local Date / Time (PST): 1988 January 30 17:58-18:03
UTC Date / Time: 1988 January 31 01:58-02:03
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: F
Station Location: Farallon Island LS, California
Station Coordinates: 37° 41' 49' (37.696944) N
 123° 00' 02" (123.000556) W
 Source: *United States Lighthouse Society*
Station Power (W): 150
Station Bearing: 309.8°
Station Distance: 333.3 statute miles (536.4 km)
Station Angle Off Best Antenna: 5.2°

Comments: CW. Sent ". . _ ." over and over.

The Farallon Island lighthouse coordinates are 37 41 57, 123 00 02. The beacon antenna was 280 yards (840 feet) 180° from the light tower. $840 / 101 = 8''$ of latitude. The beacon antenna was latitude extrapolated as 37 41 49 N

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Weak	Inaudible	Inaudible	Inaudible
Manmade Interference	Slight	–	–	–
Fading Depth (S-units)	Could not measure	–	–	–
Fade Duration (sec.)	Could not measure	–	–	–
Noise	Nil	–	–	–

CVP

Frequency (kHz): 317
Local Date / Time (PST): 1988 January 30 18:12-18:18
UTC Date / Time: 1988 January 31 02:12-02:18
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: CVP
Station Location: Helena, Montana
Station Coordinates: Unknown
Station Power (W): 100
Station Bearing: Unknown
Station Distance: Unknown
Station Angle Off Best Antenna: Unknown

Comments: Sent CW “-.-. ...- .-.-” over and over

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Inaudible	Good	Weak	Inaudible
Manmade Interference	–	Slight	Slight	–
Fading Depth (S-units)	–	Nil	Nil	–
Fade Duration (sec.)	–	–	–	–
Noise	–	Nil	Nil	–

HTN

Frequency (kHz): 320
Local Date / Time (PST): 1988 January 30 18:24-18:29
UTC Date / Time: 1988 January 31 02:24-02:29
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: HTN
Station Location: Miles City, Montana
Station Coordinates: 46° 24' 43" (46.411944°) N
 105° 56' 17" (105.938056°) W
 Source: *NAVAID Spreadsheet*
Station Power (W): 200
Station Bearing: 035.0°
Station Distance: 1036.4 statute miles (1668.0 km)
Station Angle Off Best Antenna: 35.0°

Comments: Sent ".... - -." over and over in CW.

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Inaudible	Good	Fair	Inaudible
Manmade Interference	–	Slight	Slight	–
Fading Depth (S-units)	–	Nil	Nil	–
Fade Duration (sec.)	–	–	–	–
Noise	–	Slight	Slight	–

DC

Frequency (kHz): 326
Local Date / Time (PST): 1988 January 30 18:37-18:48
UTC Date / Time: 1988 January 31 02:37-02:48
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: DC
Station Location: Princeton, British Columbia, Canada
Station Coordinates: 49° 28' 10" (49.469444°) N
 120° 31' 00" (120.516667°) W
 Source: *Canada Flight Supplement*
Station Power (W): 1000
Station Bearing: 354.4°
Station Distance: 1026.2 statute miles (1651.4 km)
Station Angle Off Best Antenna: 5.6° and 50.6° (station was heard equally well on two antennas)
Comments: Sent "DC" "-.. -.-." over and over in CW

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Inaudible	Good	Good	Fair
Manmade Interference	–	Slight	Severe	Severe
Fading Depth (S-units)	–	2 S-units	0.5	Could not measure
Fade Duration (sec.)	–	0.9	Could not measure	Could not measure
Noise	–	Nil	Nil	Nil

STI

Frequency (kHz): 333
Local Date / Time (PST): 1988 January 30 21:05-21:12
UTC Date / Time: 1988 January 31 05:05-05:12
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: STI
Station Location: Mountain Home, Idaho
Station Coordinates: 43° 06' 47" (43.113056°) N
 115° 39' 30" (115.658333°) W
 Source: *PILOTNAV*
Station Power (W): 50
Station Bearing: 013.1°
Station Distance: 598.6 statute miles (963.3 km)
Station Angle Off Best Antenna: 13.1° and 58.1° (station was heard equally well on two antennas)

Comments: Continuously sent "... - .." in CW.

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Good	Good	Fair	Inaudible
Manmade Interference	Moderate	Slight	Nil	–
Fading Depth (S-units)	Nil	Nil	Nil	–
Fade Duration (sec.)	–	–	–	–
Noise	Slight	Nil	Slight	Moderate

NO

Frequency (kHz): 351
Local Date / Time (PST): 1988 January 30 21:15-21:23
UTC Date / Time: 1988 January 31 05:15-05:23
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: NO
Station Location: Reno, Nevada
Station Coordinates: Unknown
Station Power (W): 25
Station Bearing: Unknown
Station Distance: Unknown
Station Angle Off Best Antenna: Unknown

Comments: Continuously sent “_ . _ _ _” in Morse Code

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Good	Good	Inaudible	Inaudible
Manmade Interference	Slight	Severe	–	–
Fading Depth (S-units)	Nil	Nil	–	–
Fade Duration (sec.)	–	–	–	–
Noise	Moderate	Slight	–	–

ZES

Frequency (kHz): 354
Local Date / Time (PST): 1988 January 30 18:58-19:04
UTC Date / Time: 1988 January 31 02:58-03:04
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: ZES
Station Location: Cape Scott, British Columbia, Canada
Station Coordinates: 50° 46' 56" (50.782222°) N
 128° 25' 36" (128.426667°) W
 Source: *PILOTNAV*
Station Power (W): 1000
Station Bearing: 338.5°
Station Distance: 1221.2 statute miles (1965.3 km)
Station Angle Off Best Antenna: 23.5°

Comments: Continuously sent "ZES" in CW. Tone followed call sign

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Fair	Very weak	Inaudible	Inaudible
Manmade Interference	Moderate	Severe	–	–
Fading Depth (S-units)	Nil	Nil	–	–
Fade Duration (sec.)	–	–	–	–
Noise	Nil	Nil	–	–

SA

Frequency (kHz): 356
Local Date / Time (PST): 1988 January 31 08:18-08:26
UTC Date / Time: 1988 January 31 16:18-16:26
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: SA
Station Location: Sacramento, California
Station Coordinates: 38° 26' 59" (38.449722°) N
 121° 32' 46" (121.546111°) W
 Source: *NAVAID Spreadsheet*
Station Power (W): 25
Station Bearing: 326.3°
Station Distance: 314.9 statute miles (506.8 km)
Station Angle Off Best Antenna: 11.3°

Comments: Station continuously sent "... .-" in Morse Code

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Weak	Very weak	Inaudible	Inaudible
Manmade Interference	Moderate	Slight	–	–
Fading Depth (S-units)	Nil	Nil	–	–
Fade Duration (sec.)	–	–	–	–
Noise	Moderate	Moderate	–	–

MO

Frequency (kHz): 367
Local Date / Time (PST): 1988 January 31 13:44-13:51
UTC Date / Time: 1988 January 31 21:44-21:51
Receiver Selectivity: Narrow
Receiver Mode: LSB
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: MO
Station Location: Modesto, California
Station Coordinates: 37° 34' 23" (37.573056°) N
 120° 51' 18" (120.855°) W
 Source: *Navigation Beacons*
Station Power (W): 25
Station Bearing: 325.4°
Station Distance: 243.8 statute miles (392.4 km)
Station Angle Off Best Antenna: 10.4°

Comments: Continuously sent "-- ---" in Morse Code

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Good	Fair	Inaudible	Very weak
Manmade Interference	Nil	Nil	–	Nil
Fading Depth (S-units)	None	None	–	None
Fade Duration (sec.)	–	–	–	–
Noise	Nil	Nil	Slight	Slight

HU

Frequency (kHz): 400
Local Date / Time (PST): 1988 January 31 08:42-08:51
UTC Date / Time: 1988 January 31 16:42-16:50
Receiver Selectivity: Narrow
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: Navigation beacon
Station Callsign: HU
Station Location: Sacramento, California
Station Coordinates: 38° 37' 01" (38.616944) N
 121° 36' 11" (121.603056) W
 Source: *Navigation Beacons*
Station Power (W): 25
Station Bearing: 327.1°
Station Distance: 326.1 statute miles (524.9 km)
Station Angle Off Best Antenna: 12.1°

Comments: Station continuously sent "... ..-" in Morse Code

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Fair	Very weak	Inaudible	Inaudible
Manmade Interference	Nil	Nil	–	–
Fading Depth (S-units)	Nil	Nil	–	–
Fade Duration (sec.)	–	–	–	–
Noise	Moderate	Slight	–	–

KMDY

Frequency (kHz): 850
Local Date / Time (PST): 1988 January 31 09:17-09:29
UTC Date / Time: 1988 January 31 17:17-17:29
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KMDY
Station Location: Thousand Oaks, California
Station Coordinates: 34° 12' 07" (34.201944°) N
 118° 49' 47" (118.829722°) W
 Source: *FCC File in Frequency Order*
Station Power (W): Unknown
Station Bearing: 220.5°
Station Distance: 44.1 statute miles (70.9 km)
Station Angle Off Best Antenna: 4.5°

Comments: "KMDY" call mentioned at 17:18 UTC and mention of Thousand Oaks.
 Comedy record cuts

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	4.5	Very weak	7.0 S-units	3.0 S-units
Manmade Interference	Nil	Moderate	Nil	Slight
Fading Depth (S-units)	0	0.5	0	0.5
Fade Duration (sec.)	–	Could not measure	–	0.97
Noise	Slight	Nil	Nil	Nil

KKIS

Frequency (kHz): 990
Local Date / Time (PST): 1988 January 31 09:39-09:56
UTC Date / Time: 1988 January 31 17:39-17:56
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KKIS
Station Location: Pittsburg, California
Station Coordinates: 38° 04' 49" (38.080278°) N
 121° 50' 33" (121.8425°) W
 Source: *FCC File in Frequency Order*
Station Power (W): 5000
Station Bearing: 321.1°
Station Distance: 304.9 statute miles (490.7 km)
Station Angle Off Best Antenna: 6.1°
Comments: "We are KKIS" heard at 17:52 UTC

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	5.5	4.5	Inaudible	Inaudible
Manmade Interference	Nil	Nil	–	–
Fading Depth (S-units)	0.5	0.5	–	–
Fade Duration (sec.)	Erratic	0.98	–	–
Noise	Nil	Slight	–	–

CKWX

Frequency (kHz): 1130
Local Date / Time (PST): 1988 January 30 16:53-17:07
UTC Date / Time: 1988 January 31 00:53-01:07
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: CKWX
Station Location: Vancouver, British Columbia, Canada
Station Coordinates: 49° 09' 20.88" (49.155556°) N
 123° 04' 4.80" (123.067778°) W
 Source: *fccdata.org*
Station Power (W): 50000
Station Bearing: 347.8°
Station Distance: 1027.3 statute miles (1653.3 km)
Station Angle Off Best Antenna: 12.2° and 32.8° (station was heard equally well on two antennas)
Comments: "And send your public service announcement KWX 1130 1275 Forrant(?) Street
 Vancouver"
 "CKWX news" heard at 01:04 UTC

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	S-20	S-20	Weak	Inaudible
Manmade Interference	Slight from 1130 kHz	Slight from 1130 kHz	Moderate from 1130 kHz	–
Fading Depth (S-units)	5 S-units	Nil	10 S-units	–
Fade Duration (sec.)	0.68	Not applicable - no fading	Could not measure	–
Noise	Nil	Nil	Nil	

KSZL

Frequency (kHz): 1230
Local Date / Time (PST): 1988 January 31 12:04-12:19
UTC Date / Time: 1988 January 31 20:04-20:19
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KSZL
Station Location: Barstow, California
Station Coordinates: 34° 54' 44" (34.912222°) N
 117° 01' 39" W (117.0275°) W
 Source: *FCC File in Frequency Order*
Station Power (W): 1000
Station Bearing: 077.9°
Station Distance: 75.7 statute miles (121.7 km)
Station Angle Off Best Antenna: 10.1°

Comments: 1250 kHz checked, KSZL only heard on 1230 kHz.
 "AM 1250 KSZL news" heard at 20:05 UTC
 ?Why did announcer say this? 1250?
 KSZL telephone: 619-256-2121
 Person who answered said frequency was 1230 kHz and power was
 1 kW

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Inaudible	Inaudible	S-10	S-10.5
Manmade Interference	–	–	Nil	Nil
Fading Depth (S-units)	–	–	0.75	0
Fade Duration (sec.)	–	–	0.88	–
Noise	–	–	Nil	Nil

KFIY

Frequency (kHz): 1270
Local Date / Time (PST): 1988 January 30 15:33-15:49
UTC Date / Time: 1988 January 30 23:33-23:49
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KFIY
Station Location: Tulare, California
Station Coordinates: 36° 13' 10" (36.219444°) N
 119° 18' 51" (119.314167°) W
 Source: FCC File in Frequency Order
Station Power (W): 5000
Station Bearing: 332.5°
Station Distance: 119.2 statute miles (191.8 km)
Station Angle Off Best Antenna: 17.5°

Comments: "At AM 1270 FYI" ID at 23:33 UTC

Repeated mention of station as "FYI". Had talk radio format and promotions for Michael Jackson (KABC commentator). Mention of San Joaquin Valley cities.

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	S-10	S-9.5	S-7.5	Inaudible
Manmade Interference	Slight from 1270 kHz	Moderate from 1270 kHz	Nil	Nil
Fading Depth (S-units)	1 S-unit	2 S-units	2.5 S-units	–
Fade Duration (sec.)	1.66	1.66	Could not measure	Could not measure
Noise	Nil	Nil	Nil	Slight

KPLY

Frequency (kHz): 1270
Local Date / Time (PST): 1988 January 30 15:57-16:09
UTC Date / Time: 1988 January 30-31 23:57-00:09
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KPLY
Station Location: Sparks-Reno, Nevada
Station Coordinates: 39° 32' 01" (39.533611°) N
 119° 39' 48" (119.663333°) W
 Source: FCC File in Frequency Order
Station Power (W): 5000
Station Bearing: 348.0°
Station Distance: 342.1 statute miles (550.5 km)
Station Angle Off Best Antenna: 12.0°

Comments: "and this is your oldies station AM 1270 KPLY Sparks-Reno" ID heard at 23:59 UTC

So many stations were piled up on 1270 kHz that measurements of signal quality was often impossible - couldn't tell which station was driving my meter.

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Weak	S-20	Inaudible	Inaudible
Manmade Interference	Heavy from 1270 kHz	Slight from 1270 kHz	Could not measure	Could not measure
Fading Depth (S-units)	Could not measure	5 S-units	Could not measure	Could not measure
Fade Duration (sec.)	Could not measure	1.65	Could not measure	Could not measure
Noise	Could not measure	Nil	Could not measure	Could not measure

KUHL

Frequency (kHz): 1440
Local Date / Time (PST): 1988 January 31 12:40-12:51
UTC Date / Time: 1988 January 31 20:40-20:51
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KUHL
Station Location: Santa Maria, California
Station Coordinates: 34° 59' 02" (34.983889°) N
 120° 27' 10" (120.452778°) W
 Source: *FCC File in Frequency Order*
Station Power (W): 5000
Station Bearing: 280.2°
Station Distance: 122.3 statute miles (196.9 km)
Station Angle Off Best Antenna: 34.8°

Comments: "News talk 1440 KUHL" heard at 20:40
 "KUHL" ID heard at 20:43 UTC. Station was strong at first, then faded. Couldn't take meaningful signal measurements due to Spanish station also on 1440 kHz.

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Weak	Very weak	Inaudible	Inaudible
Manmade Interference	Severe from 1440 kHz	Severe from 1440 kHz	–	–
Fading Depth (S-units)	Could not measure	Could not measure	–	–
Fade Duration (sec.)	Could not measure	Could not measure	–	–
Noise	Slight	Moderate	–	–

KGA

Frequency (kHz): 1510
Local Date / Time (PST): 1988 January 30 17:16-17:25
UTC Date / Time: 1988 January 31 01:16-01:25
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KGA
Station Location: Spokane, Washington
Station Coordinates: 47° 35' 44" (47.595556°) N
 117° 22' 15" (117.370833°) W
 Source: FCC File in Frequency Order
Station Power (W): 50000
Station Bearing: 002.9°
Station Distance: 892.0 statute miles (1435.5 km)
Station Angle Off Best Antenna: 2.9°

Comments: "Greg Blocker and 1510 KGA" heard at 01:17 UTC.

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	S-15	S-20	S-10	Weak
Manmade Interference	Nil	Nil	Nil	Severe from 1510 kHz
Fading Depth (S-units)	Nil	Nil	Nil	Could not measure
Fade Duration (sec.)	Not applicable	Not applicable	Not applicable	Could not measure
Noise	Nil	Nil	Nil	Slight

KCIN

Frequency (kHz): 1590
Local Date / Time (PST): 1988 January 31 12:58-13:11
UTC Date / Time: 1988 January 31 20:58-21:11
Receiver Selectivity: Wide
Receiver Mode: AM
Digital Demodulator: None
Type of Signal Heard: AM broadcast
Station Callsign: KCIN
Station Location: Victorville, California
Station Coordinates: 34° 32' 15" (34.5375°) N
 117° 18' 42" (117.311667°) W
 Source: FCC File in Frequency Order
Station Power (W): 500
Station Bearing: 099.9°
Station Distance: 59.0 statute miles (94.9 km)
Station Angle Off Best Antenna: 11.9°

Comments: "Hi this is Bob Hart thanking you for listening to KCIN Victorville" heard at 21:01 UTC

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Very weak	Inaudible	S-5.5	S-7.5
Manmade Interference	Severe	–	Slight	Nil
Fading Depth (S-units)	Could not measure	–	2.5	1.5
Fade Duration (sec.)	Could not measure	–	2.2	2.2
Noise	Nil	Nil	Slight	Slight

ZSJ4

Frequency (kHz): 8566
Local Date / Time (PST): 1988 January 30 19:40-19:55
UTC Date / Time: 1988 January 31 03:40-03:55
Receiver Selectivity: Narrow
Receiver Mode: USB
Digital Demodulator: MBA-RO
Type of Signal Heard: CW
Station Callsign: ZSJ4
Station Location: Silvermine, South Africa
Station Coordinates: Unknown
Station Power (W): 5000
Station Bearing: Unknown
Station Distance: Unknown
Station Angle Off Best Antenna: Unknown

Comments: Station sent "CQ CQ CQ DE ZSJ4 ZSJ4"

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	Weak	Weak	Good S-5	Good S-6
Manmade Interference	Extreme from RTTY station	Extreme from RTTY station	Slight from RTTY station	Moderate from RTTY station
Fading Depth (S-units)	Could not measure	Could not measure	2 S-units	3 S-units
Fade Duration (sec.)	Could not measure	Could not measure	14.7	5.8
Noise	Could not measure	Could not measure	Nil	Nil

RID

Frequency (kHz): 10004
Local Date / Time (PST): 1988 January 30 16:31-16:39
UTC Date / Time: 1988 January 31 00:31-00:39
Receiver Selectivity: Narrow
Receiver Mode: USB
Digital Demodulator: None
Type of Signal Heard: Time signal
Station Callsign: RID
Station Location: Irkutsk, USSR
Station Coordinates: 52° 17.5' (52.291667°) N
 104° 15' (104.250000°) E
 Source: Probably the *World Radio TV Handbook*
Station Power (W): Unknown
Station Bearing: 335.5° for the short signal path
 The station bearing for the long signal path is unknown
Station Distance: 5915.9 statute miles (9520.7 km) for the short signal path
 The station distance for the long signal path is unknown
Station Angle Off Best Antenna: 20.5°
Comments: It is unclear if this station was heard via the short or long signal path.
 Time pips heard

	Antenna A	Antenna B	Antenna C	Antenna D
Antenna Description	1200 ft (365.8 m) Northwest-southeast (315° / 135°)	1200 ft (365.8 m) North-south (000° / 180°)	1200 ft (365.8 m) Northeast-southwest (045° / 225°)	1200 ft (365.8 m) East-west (088° / 268°)
Signal Strength	S-3	S-2.5	Too weak to measure	Too weak to measure
Manmade Interference	Slight from WWV on 10000 kHz	Slight from WWV on 10000 kHz	Moderate from WWV on 10000 kHz	Moderate from WWV on 10000 kHz
Fading Depth (S-units)	2 S-units	2 S-units	Could not measure	Could not measure
Fade Duration (sec.)	2.1	1.1	Could not measure	Could not measure
Noise	Nil	Nil	Could not measure	Could not measure

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World Radio TV Handbook

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Glossary

°	Degrees
'	Minutes
”	Seconds
AM	Amplitude modulation
AWG	American Wire Gauge
CA	California
CW	Morse Code
E	East longitude
FCC	Federal Communications Commission
Freq.	Frequency
Ft	Foot
GRS80	Geodetic Reference System 1980
IF	Intermediate Frequency
ID	Identification
KABC	A talk radio station operating on 790 kHz from Los Angeles, California
kHz	Kilohertz
km	Kilometers
kW	Kilowatt
Longwave	For the purposes of this paper, the radio spectrum below 500 kHz
LS	Light Station
LSB	Lower sideband
m	Meter or meters
Mediumwave	For the purposes of this paper, the radio spectrum between 500 and 1800 kHz
N	North latitude
NAD83	North American Datum of 1983
PST	Pacific Standard Time (UTC -8 hours). The local time at the antenna test site.
RTTY	Radioteletype
S-	Signal strength units
S-units	Signal strength units measured using the receiver's signal strength meter
sec.	Seconds
Shortwave	For the purposes of this paper, the radio spectrum between 1800 and 30000 kHz
USB	Upper sideband

USSR	Union of Soviet Socialist Republics
UTC	Coordinated Universal Time (PST +8 hours)
V	Volt
W	West longitude or transmitter power in watts
WGS84	World Geodetic System 1984